

Production of Hydrogen from Post-Consumer Residues

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Objectives

- Explore feasibility of producing hydrogen from low-cost, potentially high-hydrogen-yield renewable feedstocks that could complement biomass feedstocks, increase flexibility, and improve economics of the biomass-to-hydrogen process.
- Determine efficiency of pyrolysis/reforming technology in application to readily available post-consumer wastes: plastics, trap grease, mixed biomass and synthetic polymers.

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Production section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year R,D&D Plan:

- F. Feedstock Cost and Availability
- G. Efficiency of Gasification, Pyrolysis, and Reforming Technology

Approach

- Pyrolysis or partial oxidation of biomass, plastics, and other solid organic residues in the post-consumer waste stream.
- Catalytic steam reforming of the resulting pyrolysis gases and vapors.
- Catalytic steam reforming of biomass-derived liquid streams (trap grease).

Accomplishments

- Demonstrated production of hydrogen from polypropylene (PP) by fluidized bed pyrolysis/reforming process with the yield: 34 g H₂/100 g PP, which is 80% of the stoichiometric potential.
- Demonstrated efficiency of fluidizable, attrition-resistant catalyst developed at NREL for trap grease reforming; average yield: 22 g H₂/100 g grease (60% of the stoichiometric potential).

Future Directions

- Identify the nature of catalyst deactivation and improve performance of the production of hydrogen from waste grease.
- Test and optimize pyrolysis/reforming process for complex feedstocks (textiles, mixed plastics) using commercial and NREL developed catalysts.
- Demonstrate production of hydrogen by co-processing renewable (solid and liquid biomass and wastes) and fossil (natural gas) feedstocks.

Introduction

The environmental concerns and instability of the prices of natural gas make the use of renewable biomass and wastes an attractive alternative for the production of hydrogen. In recent years, we developed a production method that combines two stages: fast pyrolysis of biomass to generate bio-oil, and catalytic steam reforming of the bio-oil to hydrogen and carbon dioxide. Because of the low cost of storage and transport of bio-oil, pyrolysis and reforming can be carried out at different locations to improve the overall process economics. Such a concept helps overcome the barrier of high feedstock cost for producing hydrogen from biomass.

This research further addresses the challenge of feedstock cost by expanding the feedstock base to other renewable low-cost materials that could be processed separately or in combination with biomass. This year we adapted the technology developed for biomass to two types of post-consumer waste materials: plastics and "trap grease". Plastics, which account for 8%-9% of today's U.S. waste stream, or about 15 Mt annually, are mostly landfilled. Potentially, the waste plastics could be used to generate 6 Mt of hydrogen per year. Waste grease is largely available throughout the country and so far is mostly discarded (i.e., not recycled or reused). The amount of grease collected in traps installed on the sewage lines of restaurants and food processing plants, and from wastewater treatment plants is about 6 kg/person/year, which has the potential for producing 0.5 Mt of hydrogen annually.

Approach

The concept proposed for plastics is a two-stage process: fast pyrolysis or gasification to convert polymers to a gas/vapor stream of monomers and other low-molecular weight compounds followed by catalytic steam reforming of this gas to yield hydrogen and carbon oxides. "Trap grease" does not require a depolymerization step and can be directly steam reformed to produce hydrogen.

Results

The production of hydrogen from plastics (polypropylene) was carried out in a two-reactor

system shown in Figure 1. Polypropylene was fed to the fluidized bed pyrolyzer, where it depolymerized to gases and vapors that reacted with steam in the second reactor – a fluidized bed catalytic reformer – to produce hydrogen, carbon oxides, and minor amounts of hydrocarbons. During a 10-hour operation, the hydrogen concentration in the product gas was above 70%, and its yield was 80% of the stoichiometric potential (complete conversion to CO_2 and H_2) as shown in Figures 2 and 3.

The production of hydrogen from "trap grease" was carried out in the single-step fluidized bed catalytic steam reforming process (liquid grease fed to the reformer). During the first year of the project, we used a commercial catalyst that did not have sufficient mechanical strength, which resulted in significant catalyst losses due to attrition and entrainment from the

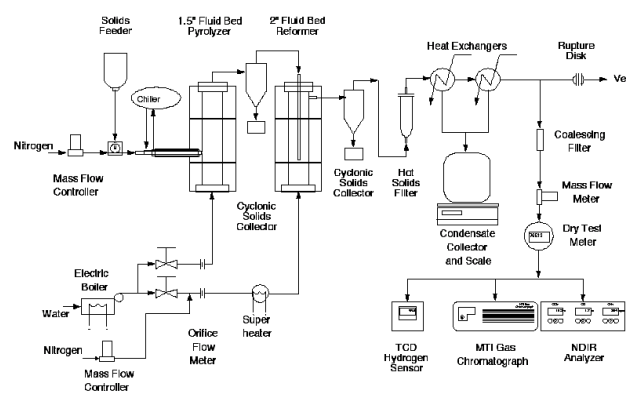


Figure 1. Fluidized Bed Integrated Pyrolysis/Reforming System

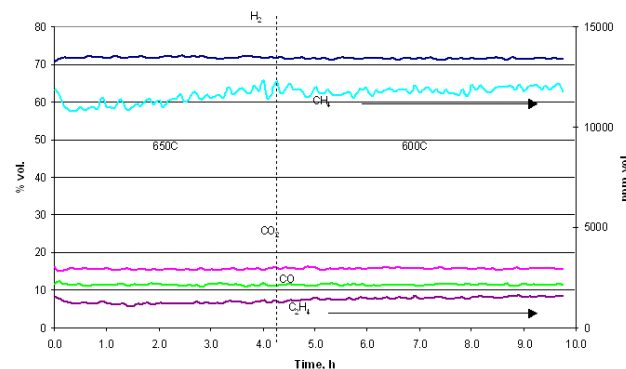


Figure 2. Product Gas Composition from Pyrolysis/Reforming of Polypropylene

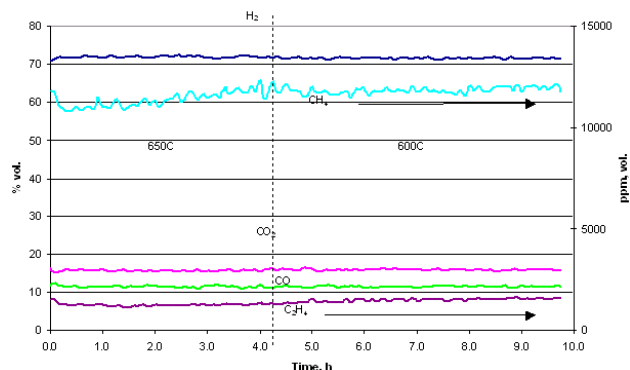


Figure 3. Yield of Hydrogen from Pyrolysis/Reforming of Polypropylene

reactor. As shown in Figures 4 and 5, the NREL developed catalyst used in this year's tests showed a satisfactory performance for 120 hours on stream, producing hydrogen with a yield greater than 60% of the stoichiometric potential, and then deactivated, probably because of the contaminants in "trap grease". The used catalyst is analyzed to identify the reason and the nature of deactivation.

Conclusions

- Using a two-reactor pyrolysis/reforming system, we demonstrated that hydrogen could be efficiently produced from plastics; 34 g hydrogen was obtained from 100 g of polypropylene, which is 80% of the stoichiometric potential.
- Reforming of "trap grease" resulted in 25 g hydrogen per 100 g grease for 115 hours of catalyst time on stream. After this time, the process performance significantly decreased due to the catalyst deactivation.

FY 2003 Publications/Presentations

1. Chornet, E. and Czernik, S., Renewable Fuels: Harnessing Hydrogen, **Nature** 2002, **418**, 928-929.

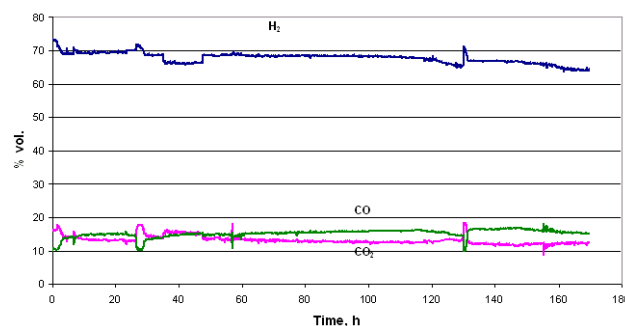


Figure 4. Product Gas Composition from Reforming of Trap Grease

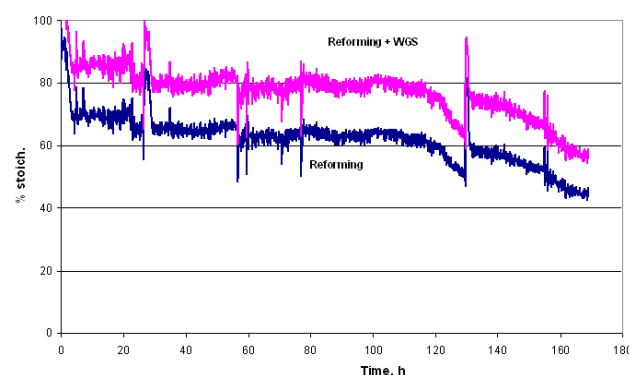


Figure 5. Yield of Hydrogen from Reforming of Trap Grease (WGS = water gas shift)

2. Czernik, S., French, R., Feik, C., Chornet, E., Hydrogen by Catalytic Steam Reforming of Liquid Byproducts from Biomass Thermoconversion Processes, **Industrial & Engineering Chemistry Research** 2002, **41**, 4209-4215.
3. Czernik, S., French, R., Feik, C., Chornet, E., Hydrogen from Biomass-derived Liquids, in Proceedings of 14th World Hydrogen Energy Conference, Montreal, Canada, June 10-14, 2002.

Special Recognitions & Awards/Patents Issued

1. Record of Invention filed with U.S. DOE.

